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Managing Strategic Innovation Globally - A window on Technologies of MEMS & Digital Communication

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Abstract

The nano-technology, genetic engineering and bio-technology have revolutionalized the Semiconductor, Pharmaceutical & Bio industry. In the present scenario, distinct industries such as mass media, telecommunication & computing are getting intermingled. This makes the present day scientists, innovators & industrialists revisit their strategies. In this context, the Micro-Electro-Mechanical-Systems (MEMS) technology promises a new development platform. This emphasizes need for strategic agility and flexible management. This paper discusses two case studies one on Digital Communication and the other on MEMS development. MEMS technology is being employed in many military and aerospace applications. On the other hand, Nokia has realized the impact of wireless communication technology. Their wide range of mobile devices are embedded with versatile services and software. This has helped them capture major share in the market.

Keywords: Strategic Agility, MEMS technology, Sensors, Digital Communication

Introduction

Modern era is characterized by most rapid and non linear changes all over. The world is witnessing a boom of knowledge-work in micro-miniaturization and in IT enabled services. The world is shrinking day by day through social networking, Google and web-2, converting it into a concept village. The nano-technology, genetic engineering and bio-technology have revolutionalized the Semiconductor, Pharmaceutical & Bio industry. Globalization of commercial networks and infrastructures is turning emerging economies such as India and China into super powers. In the present scenario, the erstwhile distinct industries such as mass media, telecommunication & computing are getting intermingled. This makes the present day researchers, scientists & industrialists re-examine their approach. Today the corporate has to act on anticipating and adapting to the fast changing market and customer need. The companies need to reinvent themselves, coordinate marketing, manufacturing and R&D. Success will be achievable only when one balances the needs of the core business with the needs of the new business. It is also required to balance the conflicts between the core unit and the new business. This is possible by creating absolutely new assumptions & biases, by making judicious use of resources from core unit and by way of strategic agility in the organization (Govindarajan 2007). In this context, the technology of Micro-Electro-Mechanical Systems (MEMS) and Nano-Electro-Mechanical Systems (NEMS) promises a new development platform. In the background of this we are discussing how innovatively these two technologies are managed for growth and development. One is on MEMS technology development and the other is on Nokia managing strategic innovation in the Digital communication technology.

Strategic Agility

It was said by Charles Darwin that "It is not the strongest of the species that survives, nor the most intelligent; it is the one that is most adaptable to change". The same theory applies to emerging technologies and to the present day companies. If you don't adapt to the change you will be superseded. 'Strategic agility' is the new word that is gaining grip these days. Strategic Agility is the ability to continuously adjust and adapt strategic direction in core business, as a function of strategic ambitions and changing circumstances, and create not just new product and services, but also new business models and innovative ways to create value for a company (Doz and Kosonen 2008). Doz and Kosonen further suggest three key enabling capabilities:

1. **Strategic Sensitivity:** both the sharpness of perception and the intensity of awareness and attention,
2. **Resource Fluidity:** the internal capability to reconfigure business systems and redeploy resources rapidly,
3. **Collective Commitment** e.g. **Leadership Unity:** the ability of the top team to make bold decisions –fast, without being bogged in "win-lose" politics at the top.

Most of the Companies have traditionally responded to change through strategic planning and the foresight offered by scenarios, or through corporate ventures and an entrepreneurial drive. In present scenario change is twofold. It is fast where ventures can provide an answer, but is also complex where strategic planning is no longer applicable because change is fast and unpredictable. The list of industrial sectors swallowed up by fast complex strategic changes are Aerospace, defense, healthcare, pharmaceuticals, energy, retailing, advertising, financial services. This emphasizes the need for strategic agility (Pathak & Sumati 2009). The companies, out-maneuvering all three dimensions of 'strategic agility', described above, excel their rivals. Further, 'evolution ability' and 'co-creation of value-system of a customer' by embedding intelligence into the design of product/ services is the invaluable management tool (Prahlad, 2004).

MEMS Technology Development

These systems can sense, control and actuate on the micro scale and function individually or in arrays to generate effects on the macro scale. MEMS include both the sensor / transducer and signal conditioning feedback & control circuitry integrated with the devices. There was a silicon revolution 30 years ago, which generated microelectronics technology. Now there is going to be second revolution in silicon in the field of MEMS technology. The same silicon will be used to fabricate moving components at micro scale, Microsystems that will sense, think, act and also communicate. MEMS are to be used because MEMS devices are physically small. They have less interference with the environment. An array of small sensors can be used for redundancy. MEMS are very precise in action. They are much lighter weight, higher in performance & reliability. They are cost effective. They have low power source requirement. MEMS can be used to provide robust and inexpensive miniaturization and integration of simple elements into more complex systems (Joshi 2005). MEMS are the systems integrated with sensors and actuators along with processing capability all on the same chip. There are two major techniques available for fabrication of MEMS - S*urface Micro-Machining (SMM)*, B*ulk Micro-*

Machining (BMM) and In addition electro-forming technique such as LIGA has opened new vista in micro-fabrication. The processing circuitry for MEMS is fabricated using the Integrated Circuit (IC) technology involving processes sequences such as CMOS, Bipolar & Bi-CMOS whereas sensors and actuating parts are fabricated using either SMM, BMM or LIGA techniques (Yazdi & Najafi 1998). The technology is developing of smart products augmented with computational power and micro-mechanisms on the same chip leading to realization of "system-on-chip".

It was in 1990, Micromechanical sensors became part of automotive technologies. Ten years later, micromechanical sensors are giving novel features for consumer electronics and for mobile devices. Today, in another ten years, truly embedded sensors based on nanostructures have become a part of our everyday intelligent environments. Nanotechnology may also augment the human sensory skills for wearable or embedded sensors. The technology would help to aggregate this immense global sensory data into meaningful information for our everyday life. This requires novel technologies and cross-disciplinary research in many ways. Nanotechnology has the capability to develop intelligent devices having key characteristic property of learning from the surrounding of the system, which is akin to biological systems that grow and adapt to the environment autonomously. In addition Nanotechnology may offer solutions for sensors that are robust & stable in harsh environmental conditions. Today mechanical sensors such as pressure and acceleration sensors have demonstrated the above mentioned requirements, but chemical or biochemical sensors are yet to show robustness and stability. Nanotechnology will drive development of new materials and new sensing elements for sensors. It will become possible to create sensors that consist of huge arrays of similar sensing elements and thus develop novel sensing principles specifically for chemical and biochemical sensors (Vaseasthaa 2005). Indian scientists had been aware of the growth potential for MEMS based devices. A National Program on Smart Materials (NPSM) was launched by DRDO formulating an India-centric technology roadmap to cultivate scientific exchange in MEMS developmental research. Under this program, various devices and materials were identified along with user agencies. The NPSM has set-up facilities for design, fabrication, integration and qualification testing of devices and materials developed under this program at various premier institutes in India. In the second level of program called NPMASS various Indian research houses such as DRDO, research institutes, defence PSUs and industries have come together under the umbrella of this program to accelerate efforts, and to keep pace with rapid progress in this emerging field. Development of acceleration sensor was one of the objectives in this program (ATIP Document).

The NPSM was launched to generate indigenous capabilities in MEMS and smart systems. The program features a high degree of inter-agency coordination and a unique program management structure. The program is sponsored by India's five R&D organizations -- Council of Scientific and Industrial Research (CSIR), the Defense Research and Development Organization (DRDO), the Department of Science and Technology (DST), the Indian Space Research Organization (ISRO) and the Department of Information Technology (DIT). MEMS research in India has intensified through two new programs one by the Aeronautical Development Agency, Bangalore, focusing on applications of MEMS and smart systems in aerospace and the by CSIR. MEMS-technology accelerometers are being employed in many military and aerospace applications not only due to reduction in price and size but also because of wider operating range, higher bandwidth and integral electronics. High degree of reliability in accelerometer performance in military applications is needed because of limited number of measurements, single shot operability, strap down or permanent integration in the system and the high cost of the system under tests.

As an outcome of NPSM, the number of Indian research groups involved in MEMS and

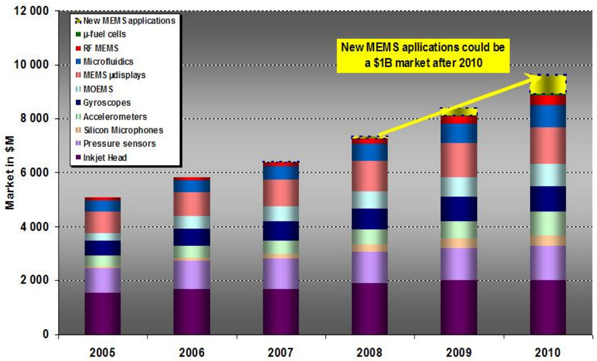


Figure 1. MEMS Technology Growth

smart systems has grown from less than 10 in the early 1990s, to more than 30 in 2002. These are spread across public-funded laboratories of the CSIR, DRDO, MIT, and a few top academic institutions and universities. Much of the MEMS research in India today has been initiated in anticipation of the country's future strategic requirements. Some MEMS systems under MEMS Research Initiatives in India development are intended for use in future versions of indigenous aircraft, satellite launch vehicles, and satellites. However, non-strategic sectors could provide a large domestic market for MEMS. NPSM program managers have rough estimates of the sizes of India's annual markets in various non-strategic sectors: $37 million in the automobile industry, $18 million in the chemical industry, $62 million in medicine (Joshi 2005). The MEMS industry worldwide had touched almost $ 6Billion in 2006 with expected annual growth rate of 14% (Eloy 2004).

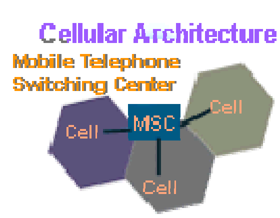
Today, MEMS accelerometers enjoy a large commercial market and they are considered to be one of the most successful micro sensors finding vast applications in precision control and guidance. The ability of such silicon accelerometers to withstand extremely high 'g' forces makes them suitable for commercial as well as military applications such as munitions, autonomous vehicles and measuring shell velocity inside an artillery gun. In view of the above, design and process development for realization of high sensitivity and high bandwidth, low cost and batch producible bulk micromachined inertial sensors has been an interesting and challenging research problem which has merited focused attention for the investigation under the present study. The necessity of realizing cost effective high-grade devices requires continued research in this area for exploring new design and exploiting fabrication technology for achieving competitive performance. Surface micro-machined and batch-fabricated accelerometers are now commercially available at low cost due to extensive research on their design and fabrication. Bulk-micromachined accelerometer consisting of a large proof mass suspended on thin beams offers higher accuracy which opens up their application in advanced navigation systems. However, one of the major problems faced in using bulk-micromachined accelerometers has been due to fabrication difficulties in monolithic integration of the proof mass with supporting electronics. Higher sensitivity of bulk micromachined accelerometers and their effective use in precision navigation systems has been the prime motivating factor for conducting innovative research for developing high performance accelerometers. This requires finding solutions to their monolithic integration with support electronics and optimization of fabrication process for developing cost effective technology for inertial measurement systems. University of Pune has concentrated its efforts on Piezoresistive acceleration sensor development. Apart from University of Pune, IIT Madras, IIT Kharagpur had been working on acceleration sensor.

MEMS Accelerometer - Case study 1 Design of a sensor based on MEMS technology, is complex process involving large number of steps. This development is recursive in nature, which involves design, fabrication, testing and modification of the design so as to ensure that system meets the specified requirements. This could turn out to be very costly due to this recursive nature as far as fabrication of prototypes is concerned. Simulation techniques when employed during early design phase would reduce foundry runs and time-consuming test set-ups. The MEMS devices are most often described by partial Differential Equations. Just as for the lumped-element models, these can be solved analytically or numerically. Analytical solutions are indispensable because they give us a superior understanding of the device physics. Numerical models, on the other hand, have the advantage that we can discover subtle effects that are important for optimization but that are neglected by simplified analytical treatments. Various software tools such as *Coventorware, Intellisuit* and *Ansys* are available today to MEMS community. Extensive use of specially designed MEMSCAD software was made to create, simulate and analyze models of sensor structures before taking up any fabrication of device. A sincere start has been made at University of Pune, India in the development of MEMS acceleration sensor incorporating novel techniques for improvement of performance factor by way of optimizing sensor sensitivity and bandwidth simultaneously (Joshi 2009). In this present work, a simple cantilever structure is created. The sensitivity improvement is achieved by changing proof mass volume. The design is modeled using CoventorWare for sensitivity, natural frequency and piezoresistive analysis. The designed structure is fabricated in Silicon (Si) n-type (100) wafer using Silicon bulk micromachining. The time dependant etch stop was used to create the structures in silicon. The Plasma Enhance Chemical Vapor Deposition (PECVD) Si_3N_4 layer was used as masking material for the Silicon micromachining. The Silicon micromachined Piezoresistive accelerometer fabrication is fabricated using two-step SBM. The convex corner compensation technique is employed successfully to protect the proof mass corners. The desire value of 4.5 kΩ-implanted resistances is achieved. The PECVD Si_3N_4 shows promising masking material capability for 300 min Si etching using KOH (Joshi 2008). This development would trigger the brainwave for the research scientists to work on many more research problems that have got triggered from above mentioned technology enabling research.

However, MEMS strategic efforts in India face hurdles in MEMS specific areas and in two generic high technology related problems. The main area of concern for India is limited facilities for microfabrication and prototyping. The other area of concern is MEMS packaging. MEMS packaging has issues like interconnects, shielding, isolation, and testing. Packaging has been niche technology in India. Prototype devices have been delayed because of the lack of experience in packaging. The two generic problems facing MEMS activities are shortage of researchers and lack of industry interest. The challenge for Indian researchers would be to innovate and make their technologies cost-competitive and get support from international collaborations (Pathak & Sumati 2009).

Digital Telecommunication Technology

In the cellular concept, frequencies allocated to the service are reused in a regular pattern of cell areas, each covered by one base station. The network architecture is very similar for most cellular systems. It contains a Switching System, an Operation and Support System, base stations



and mobile station. The Switching System contains five main functional entities:

- The Mobile Switching Center (MSC) performs the telephony switching functions for the network. It controls calls to and from other telephone and data communications networks such as Public Switched Telephone Networks (PSTN), Integrated Services Digital Networks (ISDN), Public Land Mobile Networks (PLMN) and Public Data Networks. The MSC may also be called the Mobile Telephone Switching Office (MTSO).

- The Visitor Location Register (VLR) database contains all temporary subscriber information needed by the MSC to serve visiting subscribers who are temporarily in the area of the MSC.
- The Home Location Register (HLR) database stores and manages user subscriptions. It contains all permanent subscriber information including their service profile, location information and activity status.
- The Authentication Center (AC) supports authentication and encryption functionality. It verifies the user's identity (by authentication) and ensures the confidentiality of each call (by encryption). This protects network operators against fraud.
- The Message Center (MC) supports messaging services.

Modern cellular systems use digital modulation methods, as this has several advantages over analogue transmission, including the possibility to apply advanced signal processing, such as error correction coding, security and diversity. The popular narrowband modulation methods are Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), QAM, and Continuous Phase Shift Keying as used in GSM. Other methods are Multi-Carrier Transmission, in particular OFDM and multi-carrier CDMA and Direct Sequence CDMA.

Nokia's telecom jump- Case Study 2

Nokia Corporation (Nokia) is a global manufacturer of mobile devices headquartered in Espoo, Finland. Nokia, relatively unknown company prior to 2000 was in the business of forest products, rubber and consumer goods. Nokia a relatively unknown company has become a market leader capitalizing on the digital technology. Nokia now operates through four business groups: Mobile Phones, Multimedia, Enterprise Solutions and Networks. Nokia is one organization which has taken leadership on mobiles technology from Motorola in 1999 by quickly switching over to digital wireless technology from analogue. In Q3 2007, Nokia sold over 111.7 million units worldwide, marking a 26 per cent, year-on-year growth. Nokia India had revenues of more than $3.5 billion in 2006 (Pillai 2005). Further, the Nokia Research Center has vision to become the global leader of open innovation for human mobility systems of the fused physical and digital world. One of the important dreams of the wireless industry aims at *Ambient Intelligence* i.e. computation and communication to be always available in tandem and ready to serve the user in an intelligent way (http://www.press.nokia.com/press/press-release). Nokia is the world leader in mobility, which drives the transformation and growth of converging Internet and communications industries. Their wide range of mobile devices embedded with services and software that enable people to experience music, navigation, video, television, imaging, games, business mobility and more. Recently Nokia has joined hands with Qualcomm. Qualcomm Incorporation, Headquartered in San Diego, California (US), is a leader in developing and delivering innovative digital wireless communications products and services based on CDMA and other advanced technologies. The case study on Nokia presents the finer points of managing strategic innovations.

In spite of market risks and uncertainties what matters most is the vision statement of Nokia which involves forward-looking expressions such as "believe," "expect," "anticipate," and "foresee". The statement is mainly based on predictions regarding market growth, development and profitability. This is supported by their ability to develop and implement new technology ensuring timely delivery of state-of-the-art products. The Factors that govern the strategic development of Nokia can be listed as: (http:// www.press.nokia.com/pr/)

- Timing of the roll-out of new products vis-a-vis Development in the mobile communications market
- Development of the mobile software and solutions based on 3G and subsequent new technologies
- Availability of new products and matching services by network operators
- General economic conditions globally
- The right decisions on what technologies to be developed in-house, which to be developed in partnership and which to be purchased from outside.
- Success and financial condition of the Company's partners, suppliers and customers
- Maintenance of efficient manufacturing and logistics as well as high product quality
- Ability of Nokia to have access to the complex technology involving patents and other intellectual property rights included in our products and solutions;

Further, Nokia's business is supported by six most fundamental technology priority areas – device technology leadership, smart connectivity; leading web evolution; user experience leadership; multi-functionality products and providing the preferred innovation platform.

There are numerous examples of how Nokia is applying these priority areas to deliver value on to create leading products which is way above the competition. The rapid rise in digital convergence and the advances in areas such as power management, materials, mechanics, camera, optics and electronics mean that today's smart phones can support several features on one device. Nokia has a strong track record in delivering technology market firsts. Examples include: world's first GSM call was made with a Nokia mobile phone, the first dual-mode tri-band handset for WCDMA and GSM/EDGE networks globally (Nokia 6630); the first Wi-Fi certified mobile device (both cellular and WLAN networks, Nokia 9500 Communicator); the first commercial DVB-H device (Nokia N92); the first commercial service management solution for DVB-H (Mobile Broadcast rel. 3.0) (Backgrounder 2007). Technology leadership is the key to making sure that Nokia's products differentiate from the competition by their superior quality and leading edge performance. Comparative cost advantage due to large volumes is the key in all areas of Nokia's business success. With lower costs, the company sustains higher margins, and can offer consumers more for the same cost.

Discussion

It should be the primary aim of an individual (or a leader) to utilize Co-creation of customer's experiential learning, constantly and applying it to the organizational strategic goal, (Prahlad 2004, Pathak 2006). This has evolved a model based on 'Power of full engagement' (Loehr et.al, 2003) and 'Experiential learning for passionate organizations', where, workers with ignited minds just put their creative energy solely towards the organizational excellence. The world is going through the boom of knowledge-work in micro-miniaturization and in IT enabled services. The technology of MEMS and NEMS promises a new development platform. MEMS sensors and actuators are fabricated the same chip using IC technology. The Indian strategic program on MEMS, NPSM, has set-up facilities for design, fabrication, integration and qualification testing of devices and materials development and is now running in second phase of program called NPMASS at various Indian research houses. Large number of devices such as accelerometers, pressure sensors and gas sensors are developed at premier institutes of India. The challenge for Indian researchers is to innovate and make their technologies cost-competitive and fetch support from international collaborations.

Nokia Corporation (Nokia) is a global manufacturer of mobile devices. Nokia is the world leader in mobility, which drives the transformation and growth of converging Internet and communications industries. Ability to develop and implement new technology ensuring timely delivery of state-of-the-art products is governed by many factors that are controlled by the vision statement of Nokia. Nokia's products differentiate from the competition by their superior quality and performance. Nokia's technology approach and architecture management aims to create platforms that enable these "third parties" to bring their ideas to mobile devices and eventually develop profitable business producing high-value products, applications and services. In the future, platforms supporting application development with standard web technologies will significantly increase the amount of companies and people who are able to innovate for mobile devices.

The above two case studies throw light on how strategic management of innovation can lead to technological leadership.

References

ATIP Document *MEMS Research Initiatives in India* ID: 021126AR ATIP02.051:

Backgrounder 3 (4), Web Publication, June 2007

Doz and Kosonen, *Fast Strategy*, Wharton School Publishing, 2008

Eloy J.C. MIS 07 - *Status of the MEMS Industry*, 2004.

Govindarajan Vijay; and Trimble, Chris, "*10 Rules for Strategic Innovators."* HBS Press, Boston, MA, (USA), 2007.

Joshi B.P. "*MEMS based Sensors for Armaments",* Review article for In-house journal, Shatra-shakti, 2005.

Joshi B.P. (2009), "*Study on performance enhancement and design of MEMS Piezoresistive acceleration sensor with special consideration to Sensitivity and Bandwidth optimization"*, Ph.D. thesis.

Joshi B.P., Joshi A.B., Gangal S.A., Baskar S., Natrajan K, "*Design and Fabrication of High Sensitive Piezoresistive MEMS Accelerometer."* Sensors & Transducers Journal, Vol. 91, Issue 4, 2008.

Loehr, Jin,Schwartz,Tony, *The Power of Full Engagement*, Free Press (USA), 2003.

Pathak, RC & Sumati Sidharth, "*Fast Strategy as Dominant Enabler of Organization's Accelerated Growth Trajectories."* Glogift 09 Conf at NITIE, Bombay, 2009.

Pathak, RC "*A Study of HR Flexibility and organizational Dynamics in DRDO."* An unpublished PhD Thesis, USMS, GGC Indiraprastha University, Delhi, INDIA, 2006.

Pillai, Shivthanu, *Technology Leadership*. Tata McGraw Hill Publishing Co. Ltd. New Delhi. India 2005.

Prahlad C K and Ramaswamy, Venkat, "*The Future of Competition: Co-creating Unique Value with Customers."* HBS Press (USA), & Penguin Books, New Delhi (2004), INDIA, 2004.

Vaseashtaa, D., Dimova-Malinovskab, "*Nanostructured and nanoscale devices, sensors and detectors."* Science and Technology of Advanced Materials, No. 6, 2005.

Yazdi, N., Ayazi, F. and Najafi, K., "*Micromachined inertial sensors.*" Proc. IEEE, Vol. 86, No. 8, 1998.
http://www.nokia.com/press/press-releases
http://press.nokia.com/PR/200311/926096_5.html

Biography

Dr. BP Joshi is a BE (Hons.) in Electrical Electronics Engineering from BITS, Pilani, India, ME (Mech.) in Guided Missiles and Doctorate in MEMS technology from Pune University, India. He also has Diploma in Business Management and Master of Management Sciences degree in Finance. He has 25 years of experience in design and development of critical mechatronics systems for variety of armaments and weapon systems. He has worked as a Group Director at ARDE, a leading establishment of DRDO, Ministry of Defence; handling variety of projects for defence R&D. Thirteen different armament systems developed by him are in production. He also works as a consultant/ advisor on operations, production, system design and strategic business development for defence products industry & Defence PSUs. He has more than 13 publications in various national/ international conferences and journals. Presently he is a Director/ Principal at Alard College of Engineering and Management, Pune India.

Brig. (Dr.) RC Pathak graduated from BIT, Ranchi with BE civil engineering, M. Tech & first Ph.D. in engineering in Geotechnical-Civil from IIT and second Ph.D. in Management from Indraprastha University, Delhi. Prof. Pathak has done specialization in Cold region engineering and has taken part in IXth expedition to Antarctica during 1989-90. He has served in DRDO with special contribution to glaciology and snow mechanics. Widely travelled scientist has served as a Director of DRDO's technology management institute at Mussori. He has published more than 150 papers in national & international conferences, seminars and journals. He is a recognized Ph.D. guide for University of Pune, Bharti Vidyapeeth, Tilak Maharashtra Vidyapeeth, JNU & Indraprastha University. He has held many honoured positions in various institutes. He is a life member of various societies and contributed to growth of Glogift being founder member.